

THERMALLY ENHANCED LID FOR MULTICHIP MODULES

FIELD OF THE INVENTION

The present invention relates to dissipating heat generated by integrated circuit modules; more specifically, it relates to an efficient and reduced stress package for integrated circuits.

BACKGROUND OF THE INVENTION

With the advent of multichip modules (MCMs), containing multiple integrated circuit (IC) chips each having many thousands of circuit elements, it has become possible to pack great numbers of electronic components together within a very small volume. As is well known, ICs generate significant amounts of heat during the course of their normal operation. Since most semiconductor or other solid state devices are sensitive to excessive temperatures, a solution to the problem of the generation of heat by IC chips in close proximity to one another in MCMs is of continuing concern to the industry.

A conventional approach to cooling components in electronic systems in which devices contained in MCMs are placed on printed circuit/wire boards or cards is to direct a stream of cooling air across the modules. Additionally,

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heat sinks may be attached to the module to enhance the effectiveness of the airflow.

Limitation in the cooling capacity of the simple airflow/heat sink approach to cooling has led to the use of
5 another technique, which is a more advanced approach to cooling of card-mounted MCMs. This technique utilizes heat pipe technology. Heat pipes per se are of course, well known and heat pipes in the form of vapor chambers are becoming common. In the related art, there are also
10 teachings of heat pipes/vapor chambers for dissipating the heat generated by electronic components mounted on cards. However, heat pipe/vapor chamber technology has several limitations when applied to MCMs. One limitation is the thermally induced package and especially chip stress caused
15 by a mismatch in the coefficient of thermal expansion (CTE) between the heat pipe/vapor chamber and both the integrated circuit chips and the MCM module substrate. Another limitation is when very thin wall heat pipes/vapor chamber heat vapor chambers are used, the thin walls can flex making
20 such vapor chambers un-suitable for use with land-grid array (LGA) modules which require pressure be maintained on the LGA connection.

Therefore, there is a need for an efficiently cooled MCM that employs vapor chamber cooling while minimizing CTE mismatch induced package and chip stress and is suitable for a wide range of MCM types.

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SUMMARY OF THE INVENTION

A first aspect of the present invention is an electronic package having one or more components comprising: a substrate having a first coefficient of thermal expansion; a lid attached to the substrate, the lid including a vapor chamber, the lid having a second coefficient of thermal expansion, the first coefficient of thermal expansion matched to the second coefficient of expansion; a thermal transfer medium in contact with a back surface of each component and an outer surface of a lower wall of the lid; and each component electrically connected to a top surface of the substrate.

A second aspect of the present invention is a method for dissipating heat from an electronic package having one or more components comprising: providing a substrate having a first coefficient of thermal expansion; attaching a lid to the substrate, the lid including a vapor chamber, the lid

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having a second coefficient of thermal expansion; matching the first coefficient of thermal expansion matched to the second coefficient of expansion; providing a thermal transfer medium in contact with a back surface of each component and an outer surface of a lower wall of the lid; and electrically connecting each component to a top surface of the substrate.

A third aspect of the present invention is an 18. An electronic package having one or more components comprising: a substrate having a first coefficient of thermal expansion; a lid attached to the substrate, the lid including a vapor chamber, the lid having a second coefficient of thermal expansion, the first coefficient of thermal expansion between about 25% to about 700% of the second coefficient of expansion; a thermal transfer medium in contact with a back surface of each component and an outer surface of a lower wall of the lid; and each component electrically connected to a top surface of the substrate.

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BRIEF DESCRIPTION OF DRAWINGS

The features of the invention are set forth in the appended claims. The invention itself, however, will be

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best understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

FIG. 1 is a cross-sectional view of a first embodiment
5 of a multichip module mounted on a printed circuit board having a lid according to the present invention;

FIG. 2 is a cross-sectional view of a second embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention;

10 FIG. 3 is a cross-sectional view of a third embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention;

FIG. 4 is a cross-sectional view of a fourth embodiment of a multichip module mounted on a printed circuit board
15 having a lid according to the present invention;

FIG. 5 is a cross-sectional view of a fifth embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention;

FIG. 6 is a cross-sectional view of a sixth embodiment
20 of a multichip module mounted on a printed circuit board having a lid according to the present invention;

FIG. 7 is a cross-sectional view of a seventh embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention;

5 FIG. 8 is a cross-sectional view of an eighth embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention;

FIGs. 9 is a cross-sectional view of an alternative lid
10 construction that may be used in conjunction with the fifth and sixth embodiments of the present invention;

FIG. 10 and 11 are cross-sectional views of two alternative lid constructions that may be used in conjunction with the seventh and eighth embodiments of the
15 present invention;

FIGs.12 and 13 are cross-sectional views of two alternative lid constructions that may be used in conjunction with the third, fourth, seventh and eighth embodiments of the present invention;

20 FIG. 14 is a cross-sectional view of a further lid construction that may be used in conjunction with the seventh and eighth embodiments of the present invention;

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FIGs. 15 and 16 are plan views of two alternative lid layouts of that may be used in conjunction with the fifth, sixth, seventh and eighth embodiments of the present invention;

5 FIG. 17 is a cross-section view through section 17-17 of FIG. 16; and

FIG. 18 is a cross-sectional of a lid with an attached heat sink according to the present invention.

10 DETAILED DESCRIPTION OF THE INVENTION

For the purposes of the present disclosure, the terms printed circuit board (PCB) and printed wire board (PWB) are equivalent terms. The terms "in contact" and "contacting" indicate mechanical and thermal contact.

15 FIG. 1 is a cross-sectional view of a first embodiment of a multichip module mounted on a PCB having a lid according to the present invention. In FIG. 1, MCM 100 includes a substrate 102 having a multiplicity of components 105 mounted thereto, each component having a front surface
20 110 and a back surface 115. MCM 100 is mounted to a PCB 120 by a multiplicity of solder balls 125. Substrate 102 may be a single or multi-level substrate and may be ceramic,

fiberglass or polymer based. MCM 100 also includes a lid 130. Lid 130 is mounted to substrate 102 by lid support 132 connecting the periphery of lid 130 to the periphery of substrate 102. Lid support 132 may be fabricated from the same material as lid 130 and may be integral with the lid. Alternatively, lid support 132 may be fabricated from a material different from that of lid 130. Lid support 132 may provide a hermetic seal between lid 130 and substrate 102.

10 Lid 130 includes a lower wall 135 having an outer surface 140, an upper wall 145 having an outer surface 150 and sidewalls 155 defining a vapor chamber 160. Vapor chamber 160 contains a heat transfer fluid such as, inter alia, water, freon or glycol. Front sides 110 of components 15 105 are electrically connected to a top surface 165 of substrate 102. Components 105 may be flip chip, wire-bonded or soldered to substrate 102. A thermal transfer medium 170 is in contact with back surfaces 115 of components 105 and outer surface 140 of lower wall 135 of lid 130 to enable 20 thermal contact, mechanical restraint and pressure support over the contacting region. Thermal transfer medium 170

enables heat generated by the operation of components 105 to be efficiently transferred to lid 130.

Because of the excellent heat transfer capability afforded to lid 130 by vapor chamber 160, the lid may be
5 fabricated from many different materials including but not limited to metals such as aluminum, copper, nickel, gold or Invar and other materials such as plastics, ceramics and composites. Because of the wide range of materials available, lid 130 may fabricated from a material having a
10 CTE matched to (between about 25% to 700% of the coefficient of thermal expansion) substrate 102 or from the same material as the substrate. For example, if MCM 100 is a HyperBGA™ International Business Machine Corp., Armonk, NY, in which substrate 102 is a polytetraflouroethylene (PTFE)
15 based material having a CTE of about 10-12 ppm/°C module, then lid 130 may be fabricated from an aluminum-silicon carbide composite having a CTE of about 10 ppm/°C. In order to place the least amount of thermally induced mechanical stress on components 105, lower wall 135 of lid 130 may be
20 fabricated to be thin. For example, if lid 130 were fabricated from copper (CTE about 17 ppm/°C) and components 105 were fabricated from single-crystal silicon (CTE about 3

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ppm/°C) a thin wall would reduce the stress generated by any mismatch of CTE because the wall could flex. In one example, lower wall **135** is about 250 microns or less in thickness.

5 Thermal transfer medium **170** may be thermal adhesive, thermal grease, thermal-conductive pads, phase change or other materials known in the art.

While MCM **100** has been illustrated in FIG. 1 and described above as a ball grid array (BGA) module, MCM **100**
10 may be pin grid array (PGA) module.

FIG. 2 is a cross-sectional view of a second embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention. In FIG. 2, lower wall **135A** of lid **130A** has thick protruding regions **180**
15 for maintaining the same or equivalent contact pressure, thermal contact and mechanical restraint on thin components **105A** as is maintained by thin regions **185** on thick components **105B**. Otherwise, lid **130A** is identical to lid **130** illustrated in FIG. 1 and described above. While
20 components having two different thicknesses are illustrated in FIG. 2, the second embodiment of the present invention may be extended to use with components having three or more

thicknesses that are different. For example, components may be manufactured from semiconductor wafers fabricated from different thickness (i.e 200 and 300 millimeter diameter wafers) or from devices requiring different final
5 thicknesses (i.e. logic, memory and passive devices).

FIG. 3 is a cross-sectional view of a third embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention. In FIG. 3, lid **130B** includes a separate lower wall **135B** having an outer
10 surface **140B** and a body **190** having an upper wall **145** having an outer surface **150** and sidewalls **155** defining a vapor chamber **160**. Lower wall **135B** is attached to sidewalls **155** by any suitable adhesive **195**, though a resilient adhesive is desirable if the CTE of wall **135B** is significantly different
15 from the CTE of body **190**. Lid **130B** and lower wall **135B** may be fabricated from many different materials including but not limited to metals such as aluminum, copper or Invar, plastics, ceramics and composites. Body **190** and lower wall **135B** may be fabricated from the same or different materials.
20 Body **190** may be fabricated from a material having a coefficient of CTE matched to (between about 25% to 700%) the coefficient of thermal expansion of substrate **120** while

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lower wall **135B** may be fabricated from a material having a CTE matched to (between about 50% to 700%) the coefficient of thermal expansion of the material of components **105**. For example, if MCM **100** is a HyperBGA™ International Business Machine Corp., Armonk, NY, (CTE of about 10-12 ppm/°C) and components **105** are single-crystal silicon (CTE of about 3 ppm/°C), then body **190** may be fabricated from an aluminum-silicon carbide composite (CTE of about 10 ppm/°C) and lower wall **135B** may be fabricated from glass ceramic (CTE of about 3 ppm/°C), silicon (CTE of about 3 ppm/°C) or alumina (CTE of about 6 ppm/°C). In order to place the least amount of thermally induced mechanical stress on components **105**, lower wall **135B** may be fabricated to be thin. For example, lower wall **135B** were fabricated from copper (CTE about 17 ppm/°C) and components **105** were fabricated from single-crystal silicon (CTE about 3 ppm/°C) a thin wall would reduce the stress generated by the mismatch of CTE because the wall could stretch and flex. In one example, lower wall **135B** is about 250 microns or less in thickness.

Lid support **132** may be fabricated from the same or a different material as lid **130B** and may be integral with the

lid. Lid support **132** may provide a hermetic seal between lid **130B** and substrate **102**.

FIG. 4 is a cross-sectional view of a fourth embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention. In FIG. 4, lower wall **135C** has protruding thick regions **180** for maintaining equivalent contact pressure on thin components **105A** as is maintained by thin regions **185** on thick components **105B**. Otherwise, lid **130C** is identical to lid **130B** illustrated in FIG. 3 and described above. While components having two different thicknesses are illustrated in FIG. 4, the fourth embodiment of the present invention may be extended to use with components having three or more thicknesses that are different. FIG. 4A provides an alternative cross-section to thick region **180** of lower wall **135C** (see FIG. 4). In FIG. 4A, wall thickness of region **180A** is the same as in thin region **185** (see FIG. 4) but regions **180A** are deflected toward thin components **105A** (by stamping or molding) such that contact is maintained between thermal transfer medium **170** and thin components **105A** while maintaining a thin wall.

FIG. 5 is a cross-sectional view of a fifth embodiment of a multichip module mounted on a printed circuit board having a lid according to the present invention. The fifth embodiment is similar to the first embodiment except that

5 flexural limitations caused in the case of an extremely flexible lower wall 135 are overcome in the fifth embodiment. In FIG. 5, a spreader plate 200 contacting outer surface 150 of lid 130D secures MCM 100 to PCB 120 via fasteners 205. Fasteners 205 are illustrated in FIG. 5 as

10 screws engaging threaded inserts 210 in PCB 120, but other suitable fastening means may be used, such as spring clips or rivets.

Within vapor chamber 160 are supports 215 which, under pressure, contact upper wall 145 and lower wall 135.

15 Supports 215 are aligned over components 105. Optionally, some or all of supports 215 may be aligned over some or all of components 105 and prevent excessive flexure and buckling of lower wall 135. Supports 215 spread the pressure applied to lid 130D by spreader plate 200 evenly to each component

20 105. Instead of solder balls 125 (see FIG. 1) Land Grid Array (LGA) connections 220 are illustrated between substrate 102 and PCB 120. Since LGA connections 220 are

asperity contact connections, generally some degree of pressure must be maintained on the connection to ensure good electrical conductivity. Supports **215** may be fabricated from the same material as lid **130** or a from different
5 material.

While MCM **100** has been illustrated in FIG. 5 and described above as a LGA module, MCM **100** may be BGA or a PGA module.

FIG. 6 is a cross-sectional view of a sixth embodiment
10 of a multichip module mounted on a printed circuit board having a lid according to the present invention. In FIG. 6, lower wall **135A** of lid **130E** has thick regions **180** for maintaining equivalent contact pressure on thin components **105A** as is maintained by thin regions **185** on thick
15 components **105B**. Otherwise, lid **130E** is identical to lid **130D** illustrated in FIG. 5 and described above. While components having two different thicknesses are illustrated in FIG. 6, the second embodiment of the present invention may be extended to use with components having three of more
20 thicknesses that are different.

FIG. 7 is a cross-sectional view of a seventh embodiment of a multichip module mounted on a printed

circuit board having a lid according to the present invention. In FIG. 7, lid **130G** includes a separate lower wall **135B** having an outer surface **140B** and a body **190** having an upper wall **145** having an outer surface **150** and sidewalls **155** defining a vapor chamber **160**. Lower wall **135B** is attached to sidewalls **155** by any suitable adhesive **195**, though a resilient adhesive is desirable if the CTE of wall **135B** is significantly different from the CTE of body **190**. Lid **130G** and lower wall **135B** may be fabricated from many different materials including but not limited to metals such as aluminum, copper or Invar, plastics, ceramics and composites. Body **190** may be fabricated from a material having a coefficient of CTE matched to (between about 25% to 700%) the coefficient of thermal expansion of substrate **102** while lower wall **135B** may be fabricated from a material having a CTE matched to (between about 50% to 700%) the coefficient of thermal expansion of the material of components **105**.

Within vapor chamber **160** are supports **215** contacting upper wall **145** and lower wall **135B**. Supports **215** are aligned over components **105**. Supports **215** spread the pressure applied to lid **130G** by spreader plate **200** evenly to each component **105**. Lid support **132** and supports **215** may be

fabricated from the same material or a different material as body **190**.

FIG. 8 is a cross-sectional view of an eighth embodiment of a multichip module mounted on a printed circuit board having a lid **130F** according to the present invention. In FIG. 8, lower wall **135C** has thick regions **180** for maintaining equivalent contact pressure on thin components **105A** as is maintained by thin regions **185** on thick components **105B**. Otherwise, lid **130F** is identical to lid **130G** illustrated in FIG. 7 and described above. While components having two different thicknesses are illustrated in FIG. 8, the second embodiment of the present invention may be extended to use with components having three or more thicknesses that are different. FIG. 8A provides an alternative cross-section to thick region **180** of lower wall **135C** (see FIG. 8). In FIG. 8A, wall thickness of region **180A** is the same as in thin region **185** (see FIG. 8) but region **180A** is deflected toward thin components **105A** (by stamping or molding) such that contact is maintained to thin components **105B** while maintaining a thin wall.

FIG. 9 is a cross-sectional view of an alternative lid construction that may be used in conjunction with the fifth

and sixth embodiments of the present invention. In FIG. 9, a lid 130H includes integral lower wall 135, integral upper wall 145 and integral sidewalls 155. Integral internal supports 215 join upper wall 145 and lower wall 135.

5 FIG. 10 and 11 are cross-sectional views of two alternative lid constructions that may be used in conjunction with the seventh and eighth embodiments of the present invention. In FIG. 10, a lid 130J includes a separate lower wall 135D and body 190 having an integral
10 upper wall 145 and integral sidewalls 155. Supports 215 are integral with lower wall 135D and contact upper wall 145. Lower wall 135D is joined to sidewalls 155 by adhesive 195. In FIG. 11, a lid 130K includes a separate lower wall 135B and a body 190A having integral upper wall 145, integral
15 sidewalls 155 and integral supports 215C. Supports 215C contact lower wall 135B. Lower wall 135B is joined to sidewalls 155 by adhesive 195.

FIGs.12 and 13 are cross-sectional views of two alternative lid constructions that may be used in
20 conjunction with the third, fourth, seventh and eighth embodiments of the present invention. In FIG. 12, a lid 130L includes a separate lower wall 135F, a body 190B having

an integral upper wall **145** and integral sidewalls **155A**. Lower wall **135F** is joined to sidewalls **155A** by adhesive **195A**. In FIG. 13, a lid **130M** includes a separate lower wall **135F** and a separate upper wall **145A** connected along their
5 respective periphery by a bellows **220**. Internal supports (not shown) as illustrated in FIGs 10 and 11 and described *supra*, may be used as well.

FIG. 14 is a cross-sectional view of a further lid construction that may be used in conjunction with the
10 seventh and eighth embodiments of the present invention. In FIG. 14, a lid **130N** includes separate lower wall **135F** and separate upper wall **145A** connected along their respective periphery by bellows **220**. A plurality of internal bellows **225** contact upper wall **145A** and lower wall **135F**. Each
15 internal bellows **225** is aligned over a corresponding component **105**.

FIGs. 15 and 16 are plan views of two alternative lid layouts of that may be used in conjunction with the fifth, sixth, seventh and eighth embodiments of the present
20 invention. In FIG 15, lid **130** includes sidewalls **155** enclosing vapor chamber **160**, and a plurality of separate supports **215**. Each support **215** is aligned over a

corresponding component **105**. In FIG. 16, lid **130** includes a first pair of opposite facing sidewalls **155A** and **155B**, a second set of opposite facing sidewalls **235A** and **235B**, and a set of elongated supports **215A** running between sidewalls **235A** and **235B**. The aforementioned sidewalls of lid **130** and supports **215A** enclose each sub-vapor chamber **160A**. Supports **215A** create a set of sub-vapor chambers **160A**. Each support **215A** is aligned over multiple components **105**.

FIG. 17 is a cross-section view through section 17-17 of FIG. 16. In FIG 17, support **215A** optionally includes a plurality of holes **240**. Holes **240** interconnect sub-vapor chambers **160A** (see FIG.16) to each other.

FIG. 18 is a cross-sectional of a lid with an attached heat sink according to the present invention. In FIG. 18, spreader plate **200** (see FIG. 5) is replaced with a heat sink **245** having a plurality of vertical fins **250**. Heat sink **245** may be formed from aluminum, copper, beryllium, white metal or any other suitable material with high heat conductivity.

Heat sink **245** may be fabricated from a material having a CTE matched to (between about 25% to 700%) the CTE of lid **130D** or upper wall **145** in the case of lower wall **135** being a separate piece of lid **130D** as illustrated, for example, in

FIG. 7 and described *supra*. Additionally, lower wall 135 may be fabricated from a material having a CTE matched to (between about 50% to 700%) of the CTE of components 105 in the case of lower wall 135 being a separate piece of lid 5 130D.

Alternatively, for a one piece lid 130D as illustrated, the materials of heat sink 245 and lid 130D may be chosen such that the CTE of the heat sink is matched to (between about 25% to 700%) the CTE of the lid and the CTE of the lid 10 is matched to (between about 50% to 700%) the CTE of components 105.

Thus, an efficiently cooled MCM that employs vapor chamber cooling while minimizing CTE mismatch induced package and chip stress and is suitable for a wide range of 15 component sizes, thicknesses functions and MCM types has been described.

The description of the embodiments of the present invention is given above for the understanding of the present invention. It will be understood that the invention 20 is not limited to the particular embodiments described herein, but is capable of various modifications, rearrangements, substitutions and combinations as will now

become apparent to those skilled in the art without departing from the scope of the invention. For example, a single chip module (SCM) may be substituted for the MCM illustrated. Further, internal vapor chamber supports may
5 be used in MCMs without spreader plates and spreader plates and heat sinks may be mounted to lids not having internal vapor chamber supports. Therefore, it is intended that the following claims cover all such modifications and changes as fall within the true spirit and scope of the invention.

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